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| **Date of mailing** (day/month/year)<br>04 October 2000 (04.10.00) | |
| **International application No.**<br>PCT/IB00/00065 | **Applicant's or agent's file reference**<br>131224 RO/ML/MR |
| **International filing date** (day/month/year)<br>25 January 2000 (25.01.00) | **Priority date** (day/month/year)<br>03 February 1999 (03.02.99) |
| **Applicant**<br>SEIBERLE, Hubert et al | |

1. The designated Office is hereby notified of its election made:

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PATENT COOPERATION TREATY

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## NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

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| **Applicant's or agent's file reference**<br>131224 RO/ML/MR | **IMPORTANT NOTIFICATION** |
| **International application No.**<br>PCT/IB00/00065 | **International filing date** (day/month/year)<br>25 January 2000 (25.01.00) |

1. The following indications appeared on record concerning:

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PATENT COOPERATION TREATY

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**IMPORTANT NOTIFICATION**

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1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

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(54) Title: METHOD OF IMPARTING PREFERRED ALIGNMENT IN LIQUID CRYSTAL CELLS

(57) Abstract

A liquid crystal cell has a wall able to impart both a preferred tilt and a preferred azimuthal alignment, not to mention a preferred alignment, to the liquid crystal molecules in use in the cell. The wall is made by exposing a material on it to oblique radiation which is circularly polarised or unpolarised.

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# METHOD OF IMPARTING PREFERRED ALIGNMENT IN LIQUID CRYSTAL CELLS

This invention relates to a method of imparting a property to a layer, the property being that liquid crystal molecules which may be placed on the layer would adopt a preferred alignment. The invention also relates to LCD elements incorporating a preferred alignment.

The operation of liquid crystal devices (e.g. liquid crystal displays and light valves and liquid crystal polymer elements such as optical retarders, polarisers, cholesteric filters etc.) requires controlled alignment and usually also pretilt of the liquid crystals. Currently, a mechanical rubbing technique is used to prepare surfaces which are capable of inducing alignment and pretilt.

To overcome the disadvantages of the rubbing technique, several optical methods have been developed, which use linearly polarised light and are generally called photo-alignment methods. These are disclosed in US Patents 4974941 Gibbons et al, 5784139 Chigrinov et al, 5389698 Chigrinov et al, and European Patent 0525478B (Hoffmann-La Roche et al).

While satisfactory in themselves, the methods disclosed in these patents rely on polarised light. Light sources producing polarised light are comparatively complex, which may be less suitable for mass production, and expensive. As a polariser usually absorbs at least 50% of the light, dispensing with the polariser would allow a much better usage of the light source (either a faster effect, or could use a weaker lamp). Therefore, already certain methods have been suggested, which use non-polarised light.

The generation of a pretilt angle in a nematic liquid crystal cell using a polyimide surface which has been irradiated with non-polarised U.V. light with an angle of incidence of 70° to the normal to the surface has been disclosed by Seo et al in "Asia Display 98" paper P-81, pp 795-798 and in "Liquid Crystals", 1997 vol 23 no. 6 pp 923-925. However, this method does not benefit from the potential advantages which we have identified, requiring instead very high energy input, sufficient to depolymerise the polyimide.

We have found that under certain unexpected circumstances the optical photo-alignment method referred to above also works with light that is non-linearly polarised (e.g. circularly polarised) or isotropic (unpolarised).

According to the present invention there is provided a method of making a wall of a liquid crystal cell, comprising imparting a property to a layer of a material on the wall, said property being that liquid crystal molecules placed on the material on the wall in use of the cell adopt a preferred alignment,

the method comprising exposing the material to unpolarised or circularly polarised radiation from an oblique direction,

wherein the said property further includes imparting a preferred tilt as well as a preferred azimuthal alignment to such liquid crystal molecules.

Preferably, the angle of incidence $\varphi$ of the radiation to the normal to the layer is within the range $5° \leq \varphi < 70°$, and more preferably exceeds 45°.

The radiation may be ultraviolet.

The said preferred alignment is preferably such that the longitudinal axis of the liquid crystal molecules is in the plane including the normal to the layer and the direction of the radiation. The imparted preferred tilt preferably exceeds 45° to the plane of the layer, and more preferably exceeds 75°.

In addition, the effect of the irradiation on the material may be to cross-link it, thus also improving the stability of the material and its aligning properties.

As for the radiation to which the material is exposed, this may be zonewise patterned, for example by interposing a microelement array, such as a microlens or microprism array or a suitable hologram element, between the source of the radiation and the material, so that, in said imparted property, the preferred alignment is zonewise patterned. Using such a microelement array further allows to generate locally different oblique radiation from a single radiation source even if the source itself radiates perpendicular to the material layer or the microelement array.

This method when using irradiation with unpolarised, preferably ultraviolet, light in a specific illumination geometry and with a suitable alignment layer material causes the conversion of a layer, which is isotropic before the irradiation, into an anisotropic layer. Layer and method typically have the following characteristic features:

(a) After conversion the layer has an aligning effect on a monomeric or pre-polymeric liquid crystal material put on the layer.

(b) Simultaneously with the generation of anisotropy in the layer, a cross-linking also occurs, i.e. the generation of the alignment capability and the cross-linking are based on a bimolecular photo process, but the method according to the invention can also apply to monomolecular processes, typically using azo dyes.

Where, as desirable, the layer of material has a photo-alignment sensitivity better than 2 J/cm$^2$, and the irradiation energy (measured normal to the radiation) can correspondingly be kept to less than 2 J/cm$^2$, productivity is enhanced since exposure times can then be reduced to less than 10 minutes.

The layers are photo-structurable, i.e. azimuthal alignment and tilt angle can differ in different parts of the layer (e.g. by exposing through photo-masks, holographic imaging, imaging through microelements such as microprisms, microlenses, and pixellated light switches such as micro-mirrors).

On the other hand, devices which are aligned uniformly over large areas may also be made by the method, especially LCP retarders and optical compensators for improving viewing angle of displays.

The layers can find use as alignment layers for liquid crystal devices such as displays; the displays can contain monomeric nematic, cholesteric or smectic (including chiral smectic C) liquid crystals. The operating mode may be transmission or reflection. In reflection both specular metallic or diffuse reflectors can be used, as well as reflectors made of cholesteric layers or polarisation converting optical elements (e.g. BEF foils).

The device substrate may be glass, plastic, a silicon chip, or anything else suitable.

Advantages of bypassing the necessity for polarised light include, apart from those already mentioned, general simplification of the method and making it more adaptable to mass production, and the ability to use microlens-, microprism- or similar arrays for the illumination, leading to a structured alignment with only one irradiation step, not possible with polarised light.

The invention may be used in relation to Vertically Aligned Nematic (VAN) cells, wherein the liquid crystal displays have a tilt angle of $90° \geq \theta > 75°$ on both surfaces, or in relation to Hybrid Aligned Nematic (HAN) cells, where the tilt angle

on one surface is $90° \geq \theta_1 > 75°$ and on the other is $\theta_2 \leq 30°$. Intermediate tilt angles on one or both surfaces may also have utility.

The material as such may be substantially homeotropically orienting. That is, the material may be one which induces an (azimuthally unoriented) large tilt angle, not necessarily exactly 90°, but preferably exceeding 80°, more preferably exceeding 85°, to liquid crystal molecules thereon. Particularly where large tilt angles are required, it may be advantageous to start with a substantially homeotropically orienting material, which will need (besides the azimuthal alignment) only a small adjustment of the induced tilt angle to achieve the exact required tilt.

The materials used in the invention may be photopolymerisable polymers, such as those which are also used in the known photo-alignment methods, particularly linearly photopolymerisable polymers.

The materials used can include not only photopolymerisable polymers but also monomolecular aligning materials which are inherently unstable because the photo-alignment does not cross-link them; however this does not matter if a liquid crystal polymer layer is applied while the mono molecular material is photo-aligned, as the said liquid crystal polymer can itself be cross-linked (stabilised in its aligned position), whereafter the instability of the monomolecular material has no damaging effect.

Alternatively, the material may be a polymerisable mixture which comprises (i) a liquid crystal monomer or pre-polymer having cross-linkable groups, and (ii) a photo-orientable monomer or oligomer or polymer. Such mixtures are described in UK Patent Application 9812636.0, the disclosure of which is incorporated herein by reference. Despite the distinct functions of the participating molecules, these mixtures are capable of being both oriented and cross-linked into a liquid crystal polymer. These mixtures are hence usable on the one hand as anisotropic layers in optical components or on the other hand, normally applied more thinly, as orientation layers.

It is understood that substance (i) may also be a liquid crystal polymer mixture, i.e. may contain two or more different liquid crystal molecule types. Equally, substance (ii) may be a mixture of photo-orientable molecules. A preferred photo-orientable substance (ii) comprises molecules showing a cis-trans-isomerism, particularly azo dyes. Another preferred photo-orientable substance (ii) comprises a linearly photo-polymerisable polymer.

The invention extends to a liquid crystal cell wall bearing a layer of material, the layer having the property that liquid crystal molecules placed on the layer adopt a preferred alignment, that property having been imparted to the layer by a method as set forth above.

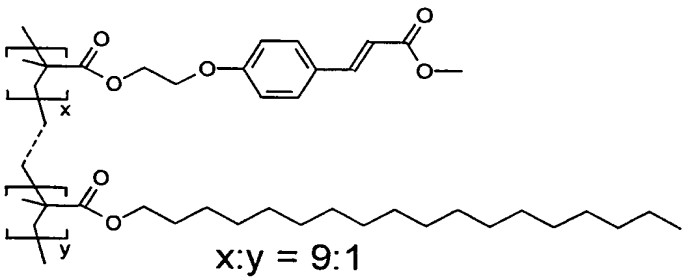
The invention further extends to a liquid crystal cell of which at least one wall in contact with liquid crystal material is as set forth above.

The invention will now be described by way of example.

Example 1 – Vertically aligned nematic (VAN) cell

A 2% solution S1 of photopolymer A in cyclopentanone was made and stirred for 30 minutes at room temperature.

Photopolymer A:




x:y = 9:1

Solution S1 was spin-coated at 2000rpm onto two indium-tin-oxide glass plate substrates which were then dried for 30 minutes on a hotplate at 130 °C. All these operations were performed in an environment of reduced ultraviolet light.

The coated substrates were subsequently exposed to isotropic ultraviolet light from a 200W high-pressure mercury lamp at an angle of incidence of 65° to the normal to the substrates, for six minutes. One edge of each substrate was arranged to lie parallel to the plane containing the normal to the substrate and the direction of the incident light during the exposure.

Ultraviolet edge filter WG295 (Schott) and a bandpass filter UG11 (Schott) were used to restrict the bandwidth of the light, which, using a light intensity meter 1000 with probe set at 320nm (Carl Süss), was found to have an intensity measured at the substrate (but normal to the incident radiation) of 2mW/cm$^2$. A parallel-sided cell was constructed using these two substrates, coatings facing each other and spaced 2.7μm apart using plastic shims. The cell was then filled at room temperature with "Liquid Crystal Mixture 8987" available from Rolic Research Ltd of Switzerland,

having a dielectric anisotropy of $\Delta\varepsilon$ = -3.5, an optical anisotropy of $\Delta n$ = 0.096, and a liquid crystal-isotropic transition temperature $T_c$ of 77.3°C.

When the cell was viewed between crossed polarisers, it appeared dark at all azimuth angles of the cell with respect to the polarisers, in other words the liquid crystal mixture was homeotropic.

Upon applying 5V 90Hz a.c. between the electrodes of the substrates, then (i) the cell became maximally transmissive to light when arranged with its edges at 45° to the directions of polarisation of the crossed polarisers, and (ii) the cell became maximally dark when arranged with its edges parallel and perpendicular to the directions of polarisation of the crossed polarisers. This demonstrates that the liquid crystal mixture had become oriented in a sense dependent upon the plane of incidence of the original layer-irradiating light (which, as will be recalled, was parallel to an edge of the substrate and hence of the cell).

Using a tilting compensator, it was established that the optical axis of the switched liquid crystal lay parallel to the line of intersection of the substrate and the plane of the original incident irradiating ultraviolet light.

Repeating the above application of alternating current but with a potential difference of only 3V, then under viewing condition (i) the cell appeared only weakly transmissive viewed normally to its plane, in other words the liquid crystal director $\vec{n}$ was only slightly tilted. To ascertain the tilt direction of the liquid crystal, the cell was tilted about that axis lying in the plane of the cell which was perpendicular to the plane including $\vec{n}$, until it again appeared dark. In this orientation, the cell was effectively being viewed along the optical axis, i.e. $\vec{n}$. This revealed that the direction of tilt of the liquid crystal with respect to the normal to the cell was the reverse of the direction of incidence of the original ultraviolet irradiation.

Whether with or without an applied voltage, the orientation of the liquid crystal was uniform without dislocations or domain boundaries. In particular, upon switching, no so-called reverse tilt domains were generated such as would arise if the liquid crystal molecules had, through too small a tilt angle in the orientation layer, been reverse-tilted in some areas.

Example 2 – Pretilt Angle Measurement

As in Example 1, two ITO-coated glass plates were spin-coated with solution S1 and dried at 130°C for 30 minutes.

Both substrates were subsequently exposed for six minutes to isotropic uv-light having an incidence angle of 65° respective to the substrate normal. The spectral range of the light was restricted by a uv-cutoff filter WG295 (Schott) and a band pass filter UG11 (Schott). The intensity of the uv-light at the position of the photosensitive layer was measured to be 2 $mW/cm^2$ using the light intensity measurement instrument of Carl Süss together with the 320 nm probe (Carl Süss).

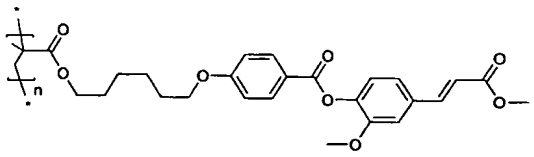
In order to measure the pretilt angle induced by the aligning layers a parallel cell was assembled with the above illuminated substrates. The cell gap was set to 20µm using two quartz fibers as spacers. Prior to filling the cell with a negative dielectric liquid crystal mixture having a dielectric anisotropy of -5.1, an optical anisotropy Δn of 0.0984, and a liquid crystal-isotropic transition temperature $T_c$ of 75.8 °C (mixture no. 9383, available from Rolic Research Ltd., Switzerland), the cell was heated to 90 °C to ensure the filling procedure to take place in the isotropic phase of the liquid crystal mixture. After filling, the cell was cooled down to room temperature at a rate of 1°C/minute.

For pretilt angle measurement the crystal rotation method was employed. As a result of the measurement the liquid crystal director was found to be tilted by 3° off the substrate normal.

Example 3 – Liquid Crystal Polymer (LCP) component

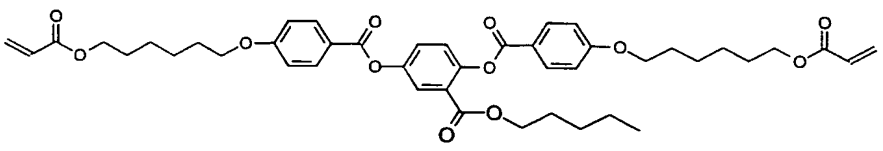
First a 2 wt% solution S2 of the photoaligning material B was prepared using cyclopentanone as a solvent. The solution was stirred for 30 minutes at room temperature.

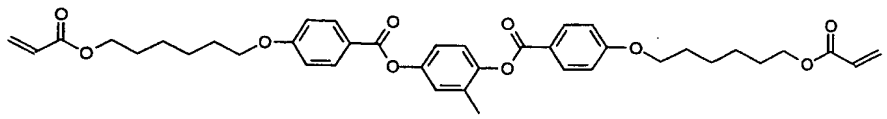
Photopolymer B:

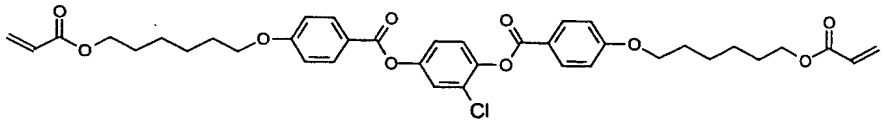


Then a mixture $M_{LCP}$ was prepared which comprised the following liquid crystalline diacrylate monomers:

Mon1:



Mon2: 

Mon3: 

In addition to the diacrylate monomers, photoinitiator IRGACURE 369 from Ciba SC as well as BHT (2,6-di-tert-butyl-4-methylphenol/"butyl hydroxytoluene") which served as an inhibitor were added to the mixture. Thus the composition of mixture $M_{LCP}$ was as follows:

| | |
|---|---|
| Mon1 | 77 wt% |
| Mon2 | 14.5 wt% |
| Mon3 | 4.7 wt% |
| Irgacure 369 | 1.9 wt% |
| BHT | 1.9 wt% |

Finally, the solution S(LCP) resulted from dissolving 10 wt% of mixture $M_{LCP}$ in anisole.

The layer preparation started with spincoating solution S2 on a 1mm thick rectangular glass substrate using 3000 rpm for 1 minute as spinning parameters. The layer was subsequently dried on a hotplate at 130°C for 30 minutes.

Then the coated substrate was exposed for six minutes to the isotropic uv-light of a 200W high pressure mercury lamp having an incidence angle of 65° relative to the substrate normal. The incidence plane of the uv-light, which was defined by the substrate normal and the light incidence direction, was aligned parallel to the longer edge of the substrate. The spectral range of the light was restricted by a uv-cutoff filter WG295 (Schott) and a band pass filter UG11 (Schott). The intensity of the uv-light at the position of the photosensitive layer was measured to be 2 $mW/cm^2$ using the light intensity measurement instrument of Carl Süss together with the 320 nm probe (Carl Süss).

When the substrate was arranged between crossed polarizers the substrate looked dark, independent of the angle between substrate edges and polarizer

transmission axes. Consequently, there was no recognizable birefringence induced in the photosensitive layer.

As a next step, a layer of $M_{LCP}$ was prepared on top of the uv-exposed photosensitive layer by spincoating solution S(LCP) with 1000 rpm for two minutes. The substrate was then heated up to 70°C, which was just above the clearing temperature $T_c$=68°C of mixture $M_{LCP}$, and cooled down to 65°C using a cooling rate of 0.1°C/min. Subsequently the $M_{LCP}$ layer was crosslinked under nitrogen atmosphere by exposing it to the light of a 150W xenon lamp for 10 minutes. A thickness of 250nm was measured for the crosslinked $M_{LCP}$ layer.

When the substrate was arranged between crossed polarizers with an angle of 45° between the substrate edges and the transmission axes of the polarizers the substrate looked gray. However, the substrate looked dark when arranging its edges either parallel or perpendicular to the polarizer transmission axes. Consequently, the $M_{LCP}$ layer was birefringent with the optical axis aligned either parallel or perpendicular to the longer substrate edge. However, using a tilting compensator the optical axis of the $M_{LCP}$ layer was found to be parallel to the longer substrate edge, which was arranged parallel to the incidence plane of the uv-light during the illumination of the photoaligning material JP265.

In addition to the azimuthal alignment, it was found that the optical axis of the $M_{LCP}$ layer was tilted respective to the substrate surface, with a mean tilt angle of about 30 ° off the substrate plane. From the viewing angle dependence of the optical appearance, it was concluded that the optical axis in the $M_{LCP}$ layer was tilted opposite to the incidence direction of the uv-light which was used for illumination of the photoaligning layer.

Consequently, the exposure to obliquely incident isotropic uv-light induced an aligning capability in the photoaligning material which was strong enough to align the liquid crystal monomers of mixture $M_{LCP}$ parallel to the incidence plane of the uv-light as well as to uniformly tilt the $M_{LCP}$ molecules out of the layer plane.

## CLAIMS

1. A method of making a wall of a liquid crystal cell, comprising imparting a property to a layer of a material on the wall, said property being that liquid crystal molecules placed on the material on the wall in use of the cell adopt a preferred alignment,

the method comprising exposing the material to unpolarised or circularly polarised radiation from an oblique direction,

wherein the said property further includes imparting a preferred tilt as well as a preferred azimuthal alignment to such liquid crystal molecules.

2. A method according to Claim 1, wherein the irradiation energy (measured normal to the radiation) is less than 2 J/cm$^2$.

3. A method according to Claim 1 or 2, wherein the radiation is ultraviolet.

4. A method according to any preceding claim, wherein said preferred alignment is such that the longitudinal axis of the liquid crystal molecules is in the plane including the normal to the layer and the direction of the radiation.

5. A method according to any preceding claim, wherein the imparted preferred tilt exceeds 45° to the plane of the layer.

6. A method according to Claim 5, wherein the imparted preferred tilt exceeds 75°.

7. A method according to any preceding claim, wherein the said material is substantially homeotropically orienting.

8. A method according to any preceding claim, wherein the angle of incidence $\varphi$ of the radiation to the normal to the layer is within the range $5° \leq \varphi < 70°$.

9. A method according to any preceding claim, wherein the angle of incidence $\varphi > 45°$.

10. A method according to any preceding claim, wherein the material is cross-linked by the irradiation.

11. A method according to any preceding claim, wherein the radiation to which the material is exposed is zonewise patterned, whereby, in said imparted property, the preferred alignment is zonewise patterned.

12. A method according to claim 11, wherein, between the source of the radiation and the material, there is interposed a microelement array.

13. A liquid crystal cell wall bearing a layer of material, the layer having the property that liquid crystal molecules placed on the layer adopt a preferred alignment, to which layer the property was imparted by a method according to any preceding claim.

14. A liquid crystal cell of which at least one wall in contact with liquid crystal material is according to claim 13.

15. A liquid crystal cell according to claim 14, which is vertically aligned nematic.

16. A liquid crystal cell according to claim 14, which is hybrid aligned nematic.

# INTERNATIONAL SEARCH REPORT

Intl. Application No
PCT/IB 00/00065

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/1337

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | GB 2 319 093 A (LG ELECTRONICS INC)<br>13 May 1998 (1998-05-13)<br>abstract; figures<br>page 8, line 2 -page 14, line 14<br>claims 18,37 | 1-16 |
| X | YOSHIDA H ET AL: "Inclined homeotropic alignment by irradiation of unpolarized UV light"<br>JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2 (LETTERS), 1 APRIL 1997, JAPAN,<br>vol. 36, no. 4A, pages L428-L431,<br>XP000732161<br>the whole document | 1-9,<br>11-16 |

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 3 April 2000 | 10/04/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Iasevoli, R |

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Intl Application No
PCT/IB 00/00065

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 788 012 A (STANLEY ELECTRIC CO LTD)<br>6 August 1997 (1997-08-06)<br>abstract<br>column 3, line 33 -column 4, line 53<br>column 8, line 40 -column 9, line 44<br>claims 1,2,8-11; figures | 1-9,<br>11-14 |
| X | TONG KUN LIM ET AL: "Tilting of liquid crystal through interaction with methyl orange molecules oriented by circularly polarized light"<br>JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2 (LETTERS), 1 OCT. 1996, PUBLICATION OFFICE, JAPANESE JOURNAL APPL. PHYS, JAPAN,<br>vol. 35, no. 10A, pages L1281-L1283,<br>XP000727756<br>the whole document | 1,2,8,9,<br>13,14 |
| X | DAE-SHIK SEO ET AL: "Investigation of pretilt angle generation in nematic liquid crystal with oblique non-polarized UV light irradiation on polyimide films"<br>LIQUID CRYSTALS, DEC. 1997, TAYLOR & FRANCIS, UK,<br>vol. 23, no. 6, pages 923-925,<br>XP002062587<br>cited in the application<br>the whole document | 1,3,4,8,<br>9 |
| A | ZILI LI: "Photopolymerization induced orientation transition in a nematic liquid crystal cell"<br>LIQUID CRYSTALS, SEPT. 1995, UK,<br>vol. 19, no. 3, pages 307-311,<br>XP000536245<br>* asbstract; section 1, paragraphs 4,5 * | 1,3,10 |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Int[redacted]l Application No
PCT/IB 00/00065

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| GB 2319093 A | 13-05-1998 | DE 19749355 A | 20-05-1998 |
| | | FR 2755518 A | 07-05-1998 |
| | | GB 2328290 A | 17-02-1999 |
| | | JP 10142608 A | 29-05-1998 |
| EP 0788012 A | 06-08-1997 | JP 2872628 B | 17-03-1999 |
| | | JP 9211468 A | 15-08-1997 |
| | | US 5912717 A | 15-06-1999 |

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/00065

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/1337

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | GB 2 319 093 A (LG ELECTRONICS INC)<br>13 May 1998 (1998-05-13)<br>abstract; figures<br>page 8, line 2 -page 14, line 14<br>claims 18,37 | 1-16 |
| X | YOSHIDA H ET AL: "Inclined homeotropic alignment by irradiation of unpolarized UV light"<br>JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2 (LETTERS), 1 APRIL 1997, JAPAN,<br>vol. 36, no. 4A, pages L428-L431,<br>XP000732161<br>the whole document | 1-9,<br>11-16 |

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 3 April 2000 | 10/04/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Iasevoli, R |

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# INTERNATIONAL SEARCH REPORT

[redacted]onal Application No
PCT/IB 00/00065

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 788 012 A (STANLEY ELECTRIC CO LTD)<br>6 August 1997 (1997-08-06)<br>abstract<br>column 3, line 33 -column 4, line 53<br>column 8, line 40 -column 9, line 44<br>claims 1,2,8-11; figures | 1-9,<br>11-14 |
| X | TONG KUN LIM ET AL: "Tilting of liquid crystal through interaction with methyl orange molecules oriented by circularly polarized light"<br>JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2 (LETTERS), 1 OCT. 1996, PUBLICATION OFFICE, JAPANESE JOURNAL APPL. PHYS, JAPAN,<br>vol. 35, no. 10A, pages L1281-L1283,<br>XP000727756<br>the whole document | 1,2,8,9,<br>13,14 |
| X | DAE-SHIK SEO ET AL: "Investigation of pretilt angle generation in nematic liquid crystal with oblique non-polarized UV light irradiation on polyimide films"<br>LIQUID CRYSTALS, DEC. 1997, TAYLOR & FRANCIS, UK,<br>vol. 23, no. 6, pages 923-925,<br>XP002062587<br>cited in the application<br>the whole document | 1,3,4,8,<br>9 |
| A | ZILI LI: "Photopolymerization induced orientation transition in a nematic liquid crystal cell"<br>LIQUID CRYSTALS, SEPT. 1995, UK,<br>vol. 19, no. 3, pages 307-311,<br>XP000536245<br>* asbstract; section 1, paragraphs 4,5 * | 1,3,10 |

1

PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

| Applicant's or agent's file reference | FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below. | |
|---|---|---|
| 138034 | | |
| International application No. | International filing date *(day/month/year)* | (Earliest) Priority Date *(day/month/year)* |
| PCT/IB 00/ 00065 | 25/01/2000 | 03/02/1999 |
| Applicant | | |
| ROLIC AG et al. | | |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing ha been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

[ ] the text is approved as submitted by the applicant.

[X] the text has been established by this Authority to read as follows:

METHOD OF IMPARTING PREFERRED ALIGNMENT IN LIQUID CRYSTAL CELLS

5. With regard to the **abstract**,

[ ] the text is approved as submitted by the applicant.

[X] the text has been established, according to Rul 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. _____

[ ] as suggested by the applicant.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

[X] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

A liquid crystal cell has a wall able to impart both a preferred tilt and a preferred azimuthal alignment, not to mention a preferred alignment, to the liquid crystal molecules in use in the cell. The wall is made by exposing a material on it to oblique radiation which is circularly polarised or unpolarised

# INTERNATIONAL SEARCH REPORT

International Application No
IB 00/00065

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/1337

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | GB 2 319 093 A (LG ELECTRONICS INC)<br>13 May 1998 (1998-05-13)<br>abstract; figures<br>page 8, line 2 -page 14, line 14<br>claims 18,37 | 1-16 |
| X | YOSHIDA H ET AL: "Inclined homeotropic alignment by irradiation of unpolarized UV light"<br>JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2 (LETTERS), 1 APRIL 1997, JAPAN,<br>vol. 36, no. 4A, pages L428-L431,<br>XP000732161<br>the whole document | 1-9,<br>11-16 |

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 3 April 2000 | 10/04/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Iasevoli, R |

1

Form PCT/ISA/210 (second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

International Application No
IB 00/00065

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 788 012 A (STANLEY ELECTRIC CO LTD)<br>6 August 1997 (1997-08-06)<br>abstract<br>column 3, line 33 -column 4, line 53<br>column 8, line 40 -column 9, line 44<br>claims 1,2,8-11; figures | 1-9,<br>11-14 |
| X | TONG KUN LIM ET AL: "Tilting of liquid crystal through interaction with methyl orange molecules oriented by circularly polarized light"<br>JAPANESE JOURNAL OF APPLIED PHYSICS, PART 2 (LETTERS), 1 OCT. 1996, PUBLICATION OFFICE, JAPANESE JOURNAL APPL. PHYS, JAPAN,<br>vol. 35, no. 10A, pages L1281-L1283,<br>XP000727756<br>the whole document | 1,2,8,9,<br>13,14 |
| X | DAE-SHIK SEO ET AL: "Investigation of pretilt angle generation in nematic liquid crystal with oblique non-polarized UV light irradiation on polyimide films"<br>LIQUID CRYSTALS, DEC. 1997, TAYLOR & FRANCIS, UK,<br>vol. 23, no. 6, pages 923-925,<br>XP002062587<br>cited in the application<br>the whole document | 1,3,4,8,<br>9 |
| A | ZILI LI: "Photopolymerization induced orientation transition in a nematic liquid crystal cell"<br>LIQUID CRYSTALS, SEPT. 1995, UK,<br>vol. 19, no. 3, pages 307-311,<br>XP000536245<br>* asbstract; section 1, paragraphs 4,5 * | 1,3,10 |

1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
[redacted]/IB 00/00065

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| GB 2319093 A | 13-05-1998 | DE 19749355 A | 20-05-1998 |
| | | FR 2755518 A | 07-05-1998 |
| | | GB 2328290 A | 17-02-1999 |
| | | JP 10142608 A | 29-05-1998 |
| EP 0788012 A | 06-08-1997 | JP 2872628 B | 17-03-1999 |
| | | JP 9211468 A | 15-08-1997 |
| | | US 5912717 A | 15-06-1999 |

PATENT COOPERATION TREATY



# PCT

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

| Applicant's or agent's file reference | FOR FURTHER ACTION | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
|---|---|---|
| 131224 RO/ML/MR | | |
| International application No. | International filing date *(day/month/year)* | Priority date *(day/month/year)* |
| PCT/IB00/00065 | 25/01/2000 | 03/02/1999 |
| International Patent Classification (IPC) or national classification and IPC<br>G02F1/1337 | | |
| Applicant<br>ROLIC AG et al. | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 19/08/2000 | 27.03.2001 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Riblet, P<br>Telephone No. +49 89 2399 2424 |

Form PCT/IPEA/409 (cover sheet) (January 1994)

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IB00/00065

## I. Basis of the r port

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
**Description, pages:**

1-9 as originally filed

**Claims, No.:**

1-16 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | |
| | No: | Claims | 1-16 |
| Inventive step (IS) | Yes: | Claims | |
| | No: | Claims | 1-16 |
| Industrial applicability (IA) | Yes: | Claims | 1-16 |
| | No: | Claims | |

2. Citations and explanations
**see separate sheet**

**VII. Certain defects in the international application**

The following defects in the form or contents of the international application have been noted:
**see separate sheet**

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
**see separate sheet**

**Re Item V**

**Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Reference is made to the following documents:
   D1: GB-A-2 319 093 (LG ELECTRONICS INC) 13 May 1998
   D2: EP-A-0 788 012 (STANLEY ELECTRIC CO LTD) 6 August 1997

2. The subject-matter of independent **claim 1** lacks novelty (Article 33(2) PCT) because each of documents D1 and D2 contains all the features of said claim, i.e. a method of making a wall of a liquid crystal cell (see the abstract in D1 and D2) comprising:
   (a) imparting a property to a layer of a material on the wall, said property being that liquid crystal molecules placed on the material on the wall in use of the cell adopt a preferred alignment (see p.9, l.11-20, Fig.7a and 7b in D1 and the abstract in D2);
   (b) exposing the material to unpolarised or circularly polarised radiation from an oblique direction (see the abstract and Fig.7a in D1 and col.3, l.50-54 in D2),
   (c) wherein said property includes imparting a preferred tilt as well as a preferred azimuthal alignment to such crystal molecules (see p.1, l.17 to p.2, l.5 and p.9, l.20-25 in D1 and col.4, l.38-43 in D2).

3. The subject-matter of **claims 2-12** lacks novelty (Article 33(2) PCT) because D1 and/or D2 contains all the features of said claims:
   **claim 2**: the irradiation energy is less than 2 J/cm$^2$ (Fig.9 in D1 and col.8, l.48-55 in D2; see also section VIII.1);
   **claim 3**: the radiation is ultraviolet (claim 8 in D1 and col.8, l.48-50 in D2);
   **claim 4**: the longitudinal axis of the liquid crystal molecules is in the plane including the normal to the layer and the direction of the radiation (col.4, l.38-45, Fig.1C and col.9, l.8-12 in D2)
   **claims 5-6**: the imparted preferred tilt exceeds 75° to the plane of the layer (p.5, l.1-3, p.11, l.3-8 and Fig.5a and 5b in D1);
   **claim 7**: the material is substantially homeotropically orienting (see p.11, l.2-3 in D1);

**claims 8-9**: the angle of incidence $\phi$ of the radiation to the normal to the layer is within the range $5° < \phi < 70°$ and may exceed 45° (see col.4, l.1-4 in D2);
**claim 10**: the material is cross-linked by the irradiation (it is implicit from p.12, l.10-11 in D1 that the material is cross-linked in the directions different from the incident direction of the radiation, see also the discussion about cross-linking in relation with polarized light p.3, l.5-13);
**claim 11**: the radiation to which the material is exposed is zonewise patterned, whereby, in said imparted property, the preferred alignment is zonewise patterned (see the abstract and Fig.11h in D1 and col.9, l.22-29 in D2);
**claim 12**: between the source of the radiation and the material, there is interposed a microelement array (see the array of micro-masks in Fig.3A and 3B and col.9, l.38-44 in D2).

4. The subject-matter of **claims 13-16** lacks novelty (Article 33(2) PCT) because document D1 contains all the features of said claims, i.e. a liquid crystal cell wall bearing a layer of material, the layer having the property that liquid crystal molecules placed on the layer adopt a preferred alignment to which layer the property was imparted by a method according to claim 1 (see the abstract, p.9, l.11-25, Fig.7a and 7b; see also section VIII.2).
The wall is further used in a liquid crystal cell (see p.14, l.9-14 and Fig.10a to Fig.10e), which is vertically aligned nematic (see p.16, l.19-20) and hybrid aligned nematic (see p.15, l.2-5 and Fig.10e).

5. In view of the cited prior art documents, the industrial applicability (Article 33(4) PCT) is clearly given for the subject-matter of all the claims.

## Re Item VII
## Certain defects in the international application

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1 to D2 is not mentioned in the description, nor are these documents identified therein.

2. Independent **claims 1** and **13** are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

**Re Item VIII**

**Certain observations on the international application**

1. The subject-matter of **claim 2** is unclear (Article 6 PCT) because the claim contains an expression in parentheses which is not related to a reference sign. In section V above, the expression in parentheses will not be considered as a restrictive feature.

2. The subject-matter of **claim 13** is unclear (Article 6 PCT) because the liquid crystal cell wall device described in said claim does not comprise any distinctive technical feature which would be specific to a particular method of alignment of the molecules. It results that the same claimed device may be obtained by any method of alignment (using linear polarised light for example).